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(54) Abstract Title
Closed-loop infrared countermeasure system using high frame rate infrared receiver

(57) An object tracking system that detects the presence of the missile, a countermeasure processor 30 receives a signal from a missile warning system 14 and characterises the missile to prioritise a trajectory signal, a track processor receives the trajectory signal and generates a pointer signal. A receiver 50 has a single focal plane array which operates at a first and second frame rates, said first rate tracking the missile over a large portion of said array to determine trajectory and said second frame rate observing the missile over a small portion of said array to receive said active signature and is steered by the pointer. The countermeasure processor directs a laser at the missile to determine its operational parameters and receive an active missile signature. The track processor updates the pointer signal and the countermeasure processor generates a jam code delivered by the laser to divert the missile.

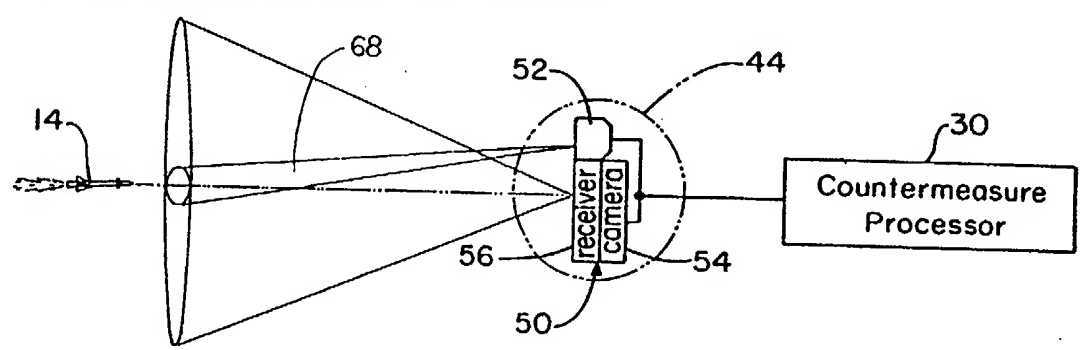

FIG.-3

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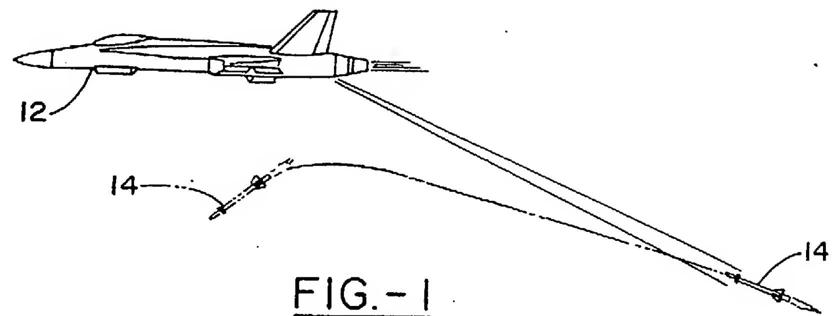
12
14
14

FIG.-1

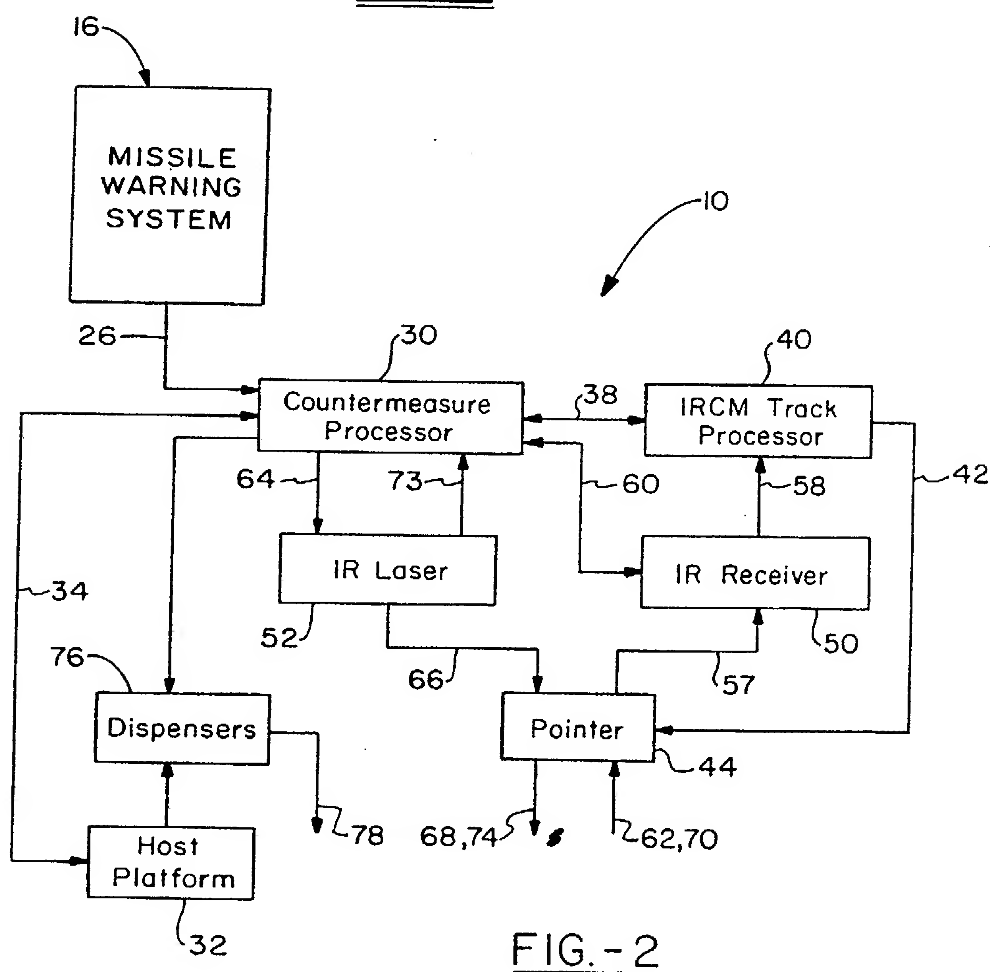
16
MISSILE WARNING SYSTEM
10
26
30
40
Countermeasure Processor
38
IRCM Track Processor
64
73
60
58
42
IR Laser
IR Receiver
34
52
50
76
66
57
Dispensers
Pointer
44
78
68,74
62,70
Host Platform
32

FIG.-2

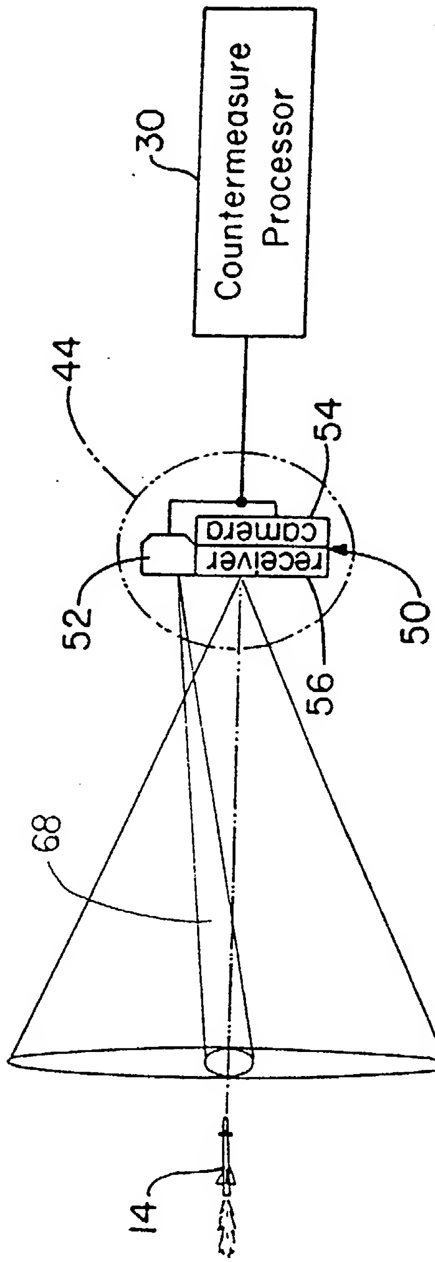
Countermeasure Processor
30
44
52
camera
receiver
54
56
50
68
14

FIG.-3

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CLOSED-LOOP INFRARED COUNTERMEASURE SYSTEM USING HIGH FRAME RATE INFRARED RECEIVER

TECHNICAL FIELD

The present invention herein resides in the art of defense systems for diverting the trajectory of incoming missiles. More particularly, the present invention relates to a system which provides simultaneous tracking and identification/classification functions with an infrared receiver having a focal plane array. Specifically, the present invention relates to a system which provides variable imaging rates to detect, jam and divert an incoming infrared missile.

BACKGROUND ART

To protect and defend military platforms, such as ships, aircraft, and ground-based installations, it is known to provide countermeasure systems that detect incoming threats such as enemy aircraft or missiles. Known systems detect incoming threats, such as infrared missiles, and then deploy defensive countermeasures in an attempt to destroy or divert the threat. These systems are referred to as open-loop systems since no immediate determination as to the type of threat or effectiveness of the countermeasure is readily available. Due to the inefficiency of the open-loop systems, closed-loop systems have been developed.

There are known performance benefits to using a directional, laser-based, closed-loop infrared countermeasure system to defeat infrared missiles. In a closed-loop system, the incoming missile is identified and the countermeasure system generates or tunes a jam code according to the specific incoming missile. The optimized jam code is directed at the missile which executes a maximum turn-away from its intended target. An additional feature of closed-loop techniques is the ability to monitor the classification and identification process during the jamming sequence. This provides a direct observation of the countermeasure effectiveness as well as an indication of the necessary corrective action required for the jam code. It will be appreciated that the benefits of the closed-loop performance system must be balanced against the cost of upgrading existing infrared directional countermeasure systems with a closed-loop capability, or against the cost of developing an entirely new closed-loop system.

One possible configuration for introducing a closed-loop receiver into a directional countermeasure system is to use a high resolution tracking sensor side-by-side with an infrared detector assembly. Accordingly, an independent receive channel, which is a

separate optical path, must be added to the detection system with a separate expensive cooled detector. The cost and size impact of such a configuration to the countermeasure system is prohibitive.

Another approach is to incorporate an infrared detector assembly into the countermeasure system and split a portion of the received optical path for the high resolution tracking sensor. Unfortunately, this approach causes at least a 50% receive loss for both the track sensor and the receiver, plus the cost for adding another cryogenically cooled detector. Another problem with this approach is that the apertures of the sensor and the receiver may not match which would require a larger overall assembly to accommodate both.

Based upon the foregoing, it is apparent that there is a need in the art for a single imaging infrared receiver having a focal plane array capable of sufficient frame rates to provide sensor data for three primary closed-loop countermeasure functions. The receiver must have a passive high resolution tracking capability, it must be able to receive and process laser signals, and finally, the receiver must be able to perform countermeasure effectiveness measurements.

DISCLOSURE OF INVENTION

In light of the foregoing, it is a first aspect of the present invention to provide a closed-loop infrared countermeasure system using a high frame rate infrared receiver.

Another aspect of the present invention is to provide a countermeasure system with a missile warning system that detects the presence of an object that may be considered a threat to a platform upon which the system is associated.

Yet another aspect of the present invention, as set forth above, is to provide a countermeasure processor, in communication with the warning system, which coordinates all of the functions and processing of the closed-loop system.

Yet another aspect of the present invention, as set forth above, is to provide a track processor which receives a trajectory signal representative of the missile path from the countermeasure processor based upon the communication received from the warning system to generate a trajectory pointer signal.

Yet a further aspect of the present invention, as set forth above, is to provide a pointer which positions itself based upon signals received from the countermeasure processor and the track processor.

Still a further aspect of the present invention, as set forth above, is to provide an infrared receiver carried by the pointer, wherein the infrared receiver has an infrared focal plane array that functions simultaneously as a laser receiver and a high resolution track sensor.

Still a further aspect of the present invention, as set forth above, is to provide a laser carried by the pointer, which is bore-sighted with the infrared receiver, which receives instructional signals and commands from the countermeasure processor, wherein a laser beam generated by the laser is initially directed toward the incoming missile threat and obtains operational characteristics therefrom which are received by the infrared receiver, which in turn are transmitted to the countermeasure processor which generates a jam code that is included with the laser beam impinging upon the incoming missile.

Still an additional aspect of the present invention, as set forth above, is to instruct the focal plane array to initiate variable imaging rates, in particular, a first imaging rate is employed to initially acquire and track the incoming threat, a faster second imaging rate is employed to provide a high resolution tracking of the incoming threat and an even faster third imaging rate is employed to obtain operational characteristics of the incoming missile.

The foregoing and other aspects of the present invention, which shall become apparent as the detailed description proceeds, are achieved by a missile tracking and deflection system for protecting a platform, comprising a missile warning system for detecting the presence of a missile and generating a warning signal, a countermeasure processor for receiving the warning signal and generating a warning report, a track processor for receiving the warning report and generating a pointer trajectory signal, a pointer for receiving the pointer trajectory signal to position the pointer toward the missile, a receiver carried by the pointer to receive a passive signature of the missile and generate a trajectory characteristic signal received by the track processor for updating the pointer trajectory signal, and a laser carried by the pointer which directs a laser beam at the missile to generate an active signature received by the receiver which generates a missile characteristic signal received by the countermeasure processor to identify the missile and generate a jam code carried by the laser beam to divert the trajectory of the missile away from the platform, the receiver observing the passive and active signatures, and generating the trajectory characteristic signal and the missile characteristic signal simultaneously.

Other aspects of the present invention are attained by a method for diverting the trajectory of a missile, comprising the steps of detecting the presence of a missile and

generating a warning signal, analyzing characteristics of the warning signal with a countermeasure processor which generates a trajectory signal, processing the trajectory signal to generate a trajectory pointer signal, receiving the pointer signal in a receiver which has a single focal plane array that tracks the trajectory of the missile and detects operational characteristics of the missile, the receiver delivering a signal to the countermeasure processor which generates a jam code employed to divert the trajectory of the missile.

Still other aspects of the present invention are attained by an object tracking system comprising a receiver for observing the object, the receiver having a focal plane array for obtaining information about the object, and a processor in communication with the receiver, the processor imaging the focal plane array over at least two frame rates, wherein a first frame rate images a large portion of the focal plane array to observe the object, and a second frame rate, faster than the first frame rate, images a smaller portion of the focal plane array to track the object.

BRIEF DESCRIPTION OF THE DRAWINGS

For a complete understanding of the objects, techniques, and structure of the invention, reference should be made to the following detailed description and accompanying drawings, wherein:

Fig. 1 is a schematic representation of a platform and an incoming missile threat;

Fig. 2 is a schematic diagram of a closed-loop infrared countermeasure system according to the present invention; and

Fig. 3 is a schematic representation of an infrared receiver tracking and delivering a jam code to an incoming missile.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to the drawings, and in particular, to Figs. 1 and 2, it can be seen that a closed-loop infrared countermeasure system, according to the present invention, is designated generally by the numeral 10. It will be appreciated that the system 10 is incorporated into a platform 12 such as a plane, ship, or ground-based installation. The system 10 is employed to detect the presence of an in-bound infrared missile 14, determine the operating characteristics of the missile, and then divert the trajectory of the missile so that it turns away from the platform 12. The system 10 may also be employed to track any moving object by observing any time varying frequency components thereof. Although an

infrared-based system is disclosed, it will be appreciated that the aspects of the present invention are applicable to other frequency-observable phenomena.

As seen in Fig. 2, the system 10 includes a missile warning system 16 which may be carried by the platform 12. The missile warning system 16 detects the presence of an object, which could be an incoming threat, by either an infrared camera, an ultraviolet camera, by sight, by radar, or any other device which can generate information about the possible location and trajectory of the object. The missile warning system 16 acquires passive information about the object and determines if the object is in fact a missile. Accordingly, the missile warning system 16 generates a hand-off signal 26 which is received by the system 10. It will be appreciated that the missile warning system 16 is a low resolution system that looks at high spatial coverage areas for the primary purpose of detecting the presence of any type of threat, such as a missile or enemy aircraft. The hand-off signal 26 includes information such as amplitude, how long the threat has been tracked, speed, intensity, and angle range from the platform 12.

A countermeasure processor 30, which provides the necessary software, hardware, and memory for controlling and coordinating the various aspects of the system 10, receives the hand-off signal 26. The countermeasure processor 30 prioritizes the threat according to the information acquired and predetermined criteria. The countermeasure processor 30 is in communication with a host platform 32 via host signal 34 for the purpose of communicating with the command structure controlling operation of the platform 12. Initially, the countermeasure processor 30 generates a trajectory signal 38 received by an infrared countermeasure track processor 40. Accordingly, the track processor 40 initiates a tracking sequence for the potential in-bound missile 14 indicated by the hand-off signal 26. In particular, the track processor 40 generates a trajectory pointer signal 42 which provides mechanical control functions to position selected components of the system 10 in the appropriate direction.

A pointer 44, as seen in Figs. 2 and 3, receives the pointer signal 42 and slews the components thereof to observe the angle and position of the in-bound missile 14. The pointer 44 carries an infrared receiver 50 and an infrared laser 52 which are bore sighted.

The infrared receiver 50 is a high frame rate, infrared focal plane array which integrally combines the function of a high resolution track sensor or a camera 54 and a laser receiver 56. In the preferred embodiment, the receiver 50 has an aperture of about 35-50 mm, although other aperture sizes could be used. The pointer 44 provides an optical path

57 for the infrared receiver 50. The infrared receiver 50 generates a trajectory characteristic signal 58 that is received by the track processor 40 for updating the trajectory pointer signal 42.

The infrared receiver 50 provides a single focal plane array to function both as a passive viewing device and an active viewing device. The receiver 50 has a relatively large field of view, wherein the focal plane array provides a full frame, 512 x 512 pixel display that generates an optical image that is converted into an electrical signal. Of course, other size focal plane arrays may be used. The receiver 50 functions as the camera 54 by employing the focal plane array to passively observe the trajectory of the missile. Since the receiver 50 employs a single focal plane array, the function of the camera 54 is inherently bore-sighted with the function of the laser receiver 56. Accordingly, both the receiver 56 and the camera 54 functionally observe substantially the same scene. As will be discussed hereinbelow, the laser receiver 56 functions to employ relatively smaller portions of the focal plane array to actively observe the trajectory of the missile. The infrared receiver 50 communicates with the countermeasure processor 30 via a missile characteristic signal 60.

After the pointer 44 slews itself toward the missile 14, the camera 54 observes a passive signature 62, typically thermal emissions generated by the missile. Other possible passive signatures that may be viewed with a similar camera are light frequencies in the visible or near visible spectrum including ultraviolet light, or acoustic signals. A relatively low frame rate, up to about 120 frames per second and preferably about 60 frames per second, is used by the track camera 54 to communicate information obtained from the passive signature 62 to the track processor 50 via the trajectory characteristic signal line 58. Accordingly, the countermeasure processor 30 instructs the track processor 40 to position the pointer 44 so that the missile 14 is centered in the focal plane array of the receiver 50. At this time, the countermeasure processor 30 instructs the track processor 40 to increase the imaging rate of the focal plane array of the receiver 50 to between about 120 to about 1000 frames per second and preferably about 400 frames per second. When this is done, the observation area of the focal plane array is reduced to a size smaller than full frame or preferably to about 32 x 32 pixels centered about the missile 14 as it appears on the focal plane array.

At this time, the countermeasure processor 30 generates an initiation signal 64 which instructs the infrared laser 52 to "illuminate" the missile 14. Upon receipt of the initiation signal 64, a laser beam 68 is generated by the laser 52 and directed at the missile 14.

Accordingly, as the laser beam 68 impinges upon the missile 14, an active signature 70 is reflected and received by the laser receiver 56 aspect of the receiver 50. The countermeasure processor 30 then instructs the receiver 50 to employ a sampling rate of up to 50,000 frames per second and preferably about 32,000 frames per second over an even smaller sub-array size of about 16 x 16 pixels. In other words, the ultra-fast imaging rate may be applied to a pixel array of 1 x 1 up to an array size employed for the prior imaging rate. It will be appreciated that these imaging rates are only limited by the operational characteristics of the receiver 50. The point spread image of the active signature 70 is processed in the manner described above to maintain the high resolution track on the missile 14. Those skilled in the art will appreciate that the laser receiver 56 employs pixel detectors, such as photo diodes, which are digitally sampled and processed by the countermeasure processor 30 via the optical path 57 and the missile characteristic signal 60. The processor 30 in turn performs a Fourier analysis of the amplitude modulation or time varying characteristics of the optical path 57 and/or the signal 60 to determine operational characteristics of the missile 14. The processor 30 monitors the performance of the laser 52 via a signal line 73.

Once the active signature 70 is returned from the missile 14, the infrared receiver 50 simultaneously generates corresponding updated signals for the trajectory characteristic signal 58, which in turn updates the pointer trajectory signal 42, and the missile characteristic signal line 60. At this time, the countermeasure processor 30 analyzes the components of the active signature 70 and generates a jam code 74 for inclusion with the laser beam 68. Accordingly, the missile 14 is diverted from the actual platform and eventually self-destructs, as the jam code 74 is included with the laser beam 68. A countermeasure effectiveness measurement is performed by the countermeasure processor 30 by simultaneously examining dynamic track and classification and identification information provided by the signature 70. As such, if the jam code 74 is found to be ineffective, the countermeasure processor 30 can immediately make adjustments thereto.

If desired, the system 10 may also provide dispensers 76 which eject infrared expendable devices 78 that may also be used to divert the trajectory and/or path of the incoming missile 14. The dispensers 76 are in communication with the host platform 32 so that it may be monitored thereby.

Based upon the foregoing structure and method of the use presented above, the system 10 effectively analyzes a trajectory of an incoming missile and its operational characteristics

and generates a jam code to divert the trajectory of the missile away from the platform. Previous approaches to closed-loop laser infrared countermeasure required the use of a separate laser receiver to collect interrogation signals from an infrared missile and a separate infrared focal plane array camera for high resolution tracking of the threat. The separate laser interrogation receiver has significant negative system impacts on the cost, size, weight, power efficiency, performance, reliability, and maintainability. By employing the present invention, wherein the laser receiver function and the high resolution tracking function are incorporated into a single, infrared focal plane array, these system impacts are eliminated or greatly reduced. Still yet another advantage of the present invention is that current open-loop systems may be converted to closed-loop systems with substantially improved performance in defending from missile attacks. Moreover, the present invention avoids adding additional operating equipment which would require the splitting of signals and reducing the strength thereof to the detriment of the host platform 32. Another advantage of the present invention is that the same signal may be processed with a relatively smaller aperture than may be otherwise provided.

Thus, it can be seen that the objects of the invention have been satisfied by the structure and use of the invention as presented above. While in accordance with the patent statutes, only the best mode and preferred embodiment of the invention has been presented and described in detail, it is to be understood that the invention is not limited thereto or thereby. Accordingly, for an appreciation of the true scope and breadth of the invention, reference should be made to the following claims.

CLAIMS

1. An object tracking system comprising: a receiver for observing the object, said receiver having a focal plane array for obtaining information about the object; and a processor in communication with said receiver, said processor imaging said focal plane array over at least two frame rates, wherein a first frame rate images a large portion of said focal plane array to observe the object, and a second frame rate, faster than said first frame rate, images a smaller portion of said focal plane array to track the object.

2. The system according to claim 1, further comprising: a laser bore sighted with said receiver and in communication with said processor, said processor activating said laser to direct a laser beam toward the object, whereupon said processor initiates a third frame rate and said receiver monitors a returned laser beam signal from the object.

3. The system according to claim 2, wherein said processor receives said returned laser beam signal and images an even smaller portion of said focal plane array at an even faster third frame rate to observe the effect of said laser beam on the object.

4. An object tracking system substantially as described herein with reference to and as illustrated in the accompanying drawings.

Amendments to the claims have been filed as follows

1. An object tracking system comprising: a receiver for observing the object, said receiver having a focal plane array for obtaining information about the object; and a processor in communication with said receiver, said processor imaging said focal plane array over at least two frame rates, wherein a first frame rate images a large portion of said focal plane array to observe the object, and a second frame rate, faster than said first frame rate, images a smaller portion of said focal plane array to track the object.

2. The system according to claim 1, further comprising: a laser bore sighted with said receiver and in communication with said processor, said processor activating said laser to direct a laser beam toward the object, whereupon said processor initiates a third frame rate and said receiver monitors a returned laser beam signal from the object.

3. The system according to claim 2, wherein said processor receives said returned laser beam signal and images an even smaller portion of said focal plane array at an even faster third frame rate to observe the effect of said laser beam on the object.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0310788.5	**Examiner:**	Brian Hughes
Claims searched:	1 to 4	**Date of search:**	27 June 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
		NONE

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{V}:

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Worldwide search of patent documents classified in the following areas of the IPC^{7}:

F41G, F41H, G01S

The following online and other databases have been used in the preparation of this search report :

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